

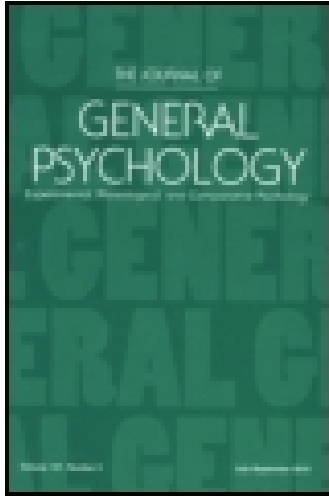
This article was downloaded by: [McMaster University]

On: 21 December 2014, At: 00:23

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954

Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



The Journal of General Psychology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/vgen20>

The Measurement of "Spontaneous Activity"

B. F. Skinner^{a b}

^a Laboratory of General Physiology, Harvard University, USA

^b National Research Council Fellow

Published online: 06 Jul 2010.

To cite this article: B. F. Skinner (1933) The Measurement of "Spontaneous Activity", The Journal of General Psychology, 9:1, 3-23, DOI: [10.1080/00221309.1933.9920910](https://doi.org/10.1080/00221309.1933.9920910)

To link to this article: <http://dx.doi.org/10.1080/00221309.1933.9920910>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan,

sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

THE MEASUREMENT OF "SPONTANEOUS ACTIVITY"*

From the Laboratory of General Physiology, Harvard University

B. F. SKINNER¹

I

In the traditional use of the term "spontaneous activity" no attempt is made to distinguish between the various forms of the behavior of the organism. Taken in this broad sense, a quantitative measure of the exhibited activity is practically impossible. An indirect measure may be obtained from some aspect of the metabolism of the organism, its heat production, for example, or its oxygen consumption. But a direct measure of behavior, as such, must provide for each of the many forms the behavior may assume and is consequently very difficult. If we suppose, in spite of the technical difficulties involved, that it is nevertheless possible, and that a separate measure of each form of behavior can be made available, we have still to provide for the reduction of the resulting data to a common unit expressing "activity."

The use of a "running-wheel" supplies a practical solution. What it does, in effect, is to select one kind of activity for measurement and so far as possible to suppress all other kinds. It utilizes for the purpose a form of behavior easily measured, with a result expressible in simple units. Thus, if a rat is confined in a small cage with access to a running-wheel, its "activity" during any given period of time can be read from a counter on the wheel simply as distance run. This is a convenient procedure and has been widely used.

It is obvious, however, that the method involves several broad assumptions. The behavior of the rat in the wheel will depend, first of all, upon the properties of the wheel. It will depend also upon the degree of suppression of other kinds of behavior and upon the periodic appearance of those kinds which cannot be suppressed if

*Accepted for publication by W. J. Crozier of the Editorial Board and received in the Editorial Office, August 23, 1932.

¹National Research Council Fellow.

any considerable interval of time is being dealt with. It will depend also upon certain incidental changes in the environment, which are often not eliminated, as, for example, in illumination, sound, and temperature. In an experiment concerned chiefly with the internal comparison of a group of total distances run, measured under the same conditions, these factors are not necessarily important. But in any exact analysis of the behavior of the rat they must be taken into account.

It is the purpose of the present paper to examine some of the variables of which behavior in a running-wheel may be a function. A standard wheel, a method of recording, and an experimental procedure are described. Sample records are given to illustrate the application of the method to several problems concerning spontaneous activity. The nature of the general phenomenon is also briefly discussed.

II

In considering such a system as a rat in a running-wheel it will be convenient to make several simplifying assumptions. We shall not need to examine the specific postural and progressive reflexes evoked as the rat runs, or their interaction. We shall assume that only a single force is exerted upon the wheel and that this acts tangentially. We shall assume that the running is always in a plane normal to the axis of the wheel, and that, when the rat starts running, a given velocity (V) *relative to the running-surface* is developed during a very brief period of time (which can be ignored) and is then constantly maintained until the rat stops. We shall also assume for the moment that the wheel is frictionless. The behavior of such a system will depend almost wholly upon the ratio of the weight of the rat to the moment of inertia of the wheel, expressing the latter in grams at the radius of the running-surface. We may consider three cases.

a. Where the moment of inertia is negligible, the absolute position of the rat is not changed, and the velocity (V) is assumed entirely by the running-surface.

b. As an intermediate case, suppose the weight of the rat and the moment of inertia to be approximately equal. The resting rat stands at a position of equilibrium with its center of gravity directly above the lowest point in the perimeter of the wheel. The acceleration at the start is divided equally between wheel and rat. With the

acquired absolute velocity of $V/2$ the rat moves out of the position of equilibrium at A (Figure 1) toward a position as at B . This introduces a new force tending to accelerate the wheel, namely, the gravitational component, equal to the product of the weight of the rat into the sine of the angle of displacement (α' in the construction in Figure 1). Since we have assumed a constant relative velocity, the movement toward B continues until the absolute velocity of the wheel has become equal to V . But the rat is then in a position as at B . Consequently the wheel is further accelerated, and the velocity of the rat becomes negative. The rat passes through position A , having at that point a negative velocity of $V/2$, toward a position as at C , where the gravitational component brings the velocity of the rat again to zero and of the surface again to V . The gravitational component then further reduces the velocity of the wheel, giving the rat a positive velocity which reaches $V/2$ at A , completing the cycle. If we hold strictly to our assumptions of a constant relative velocity and a frictionless wheel, the rat will oscillate in this fashion about A , continuing meanwhile to run with the constant relative velocity V . The wheel and the running rat may be treated simply as a pendulum, the laws of which apply to the present system.

When the rat stops, the relative velocity is reduced to zero, and the rat is carried toward C until the gravitational component reduces

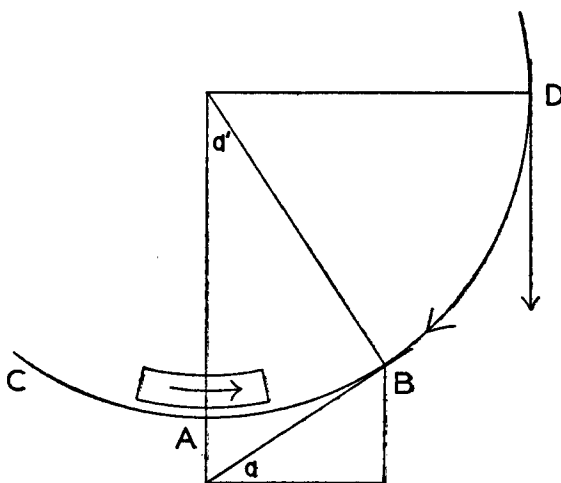


FIGURE 1

the absolute velocity to zero. From this point the wheel and the now resting rat again behave as a pendulum.

c. In the third case, where the moment of inertia is greater than the weight of the rat, case *b* holds, but the movement of the rat from the position *A* is proportionately greater in both directions.

The effect of friction, which we have thus far ignored, is, first, to damp any oscillation about *A*, and, second, to determine the point at which equilibrium is reached by the running rat. When oscillation has been eliminated, the rat runs at a position such that the gravitational component is just equal to the friction of the wheel, the latter being expressed in grams acting vertically at the radius of the running-surface (*D* in Figure 1). This relationship will be considered again later.

A constant relative velocity cannot actually be expected. The change in slope resulting from any movement out of the *A* position usually reduces the relative velocity on the *B* side and increases it on the *C*. The effect of the change is to reduce the extent of any oscillation. There may also be changes in velocity not related to the system, the effect of which is either to amplify or to reduce an oscillation.

It is obvious that the behavior of the rat will vary with these properties of the wheel. The energy expended in running at a constant velocity is in part a function of the friction of the wheel. The work done in starting and stopping or in making any other change in velocity depends upon the moment of inertia. Apart from considerations of energy-output, we must note also certain effects of oscillation and of the translation that accompanies any change in relative velocity (2). An "emotional" effect is clearly seen in the excitement of a rat placed for the first time in a wheel of relatively great moment of inertia. The "emotional" effect may adapt out with time, but the very numerous postural changes accompanying rotation and translation remain superimposed upon the simple running. Their extent is, again, a function of the moment of inertia of the wheel.

If we select running as a particular form of activity to be measured, we must specify the conditions under which it is to be observed. Otherwise the term may refer to quite different kinds of behavior. Theoretically, any given set of specifications could be used to define a standard wheel. There is good reason, however, to prefer that set which duplicates as nearly as possible the conditions of

running on a level surface. This is not only the most natural form of the behavior (the most often observed under ordinary conditions), and consequently the least disturbing, but also mechanically the simplest. The running-wheel may, in short, be regarded as a substitute for a level straightaway, which would be the ideal instrument for the measurement of running if it were not obviously impractical; and the wheel should be constructed accordingly.

The characteristics of a level straightaway cannot, of course, be exactly reproduced in a wheel. In order to duplicate the work expended in any acceleration, the wheel must have a moment of inertia equal to the weight of the rat. But this introduces at once the rotational and translational effects we have already noted, which are lacking in straightaway running. Beside this inherent difficulty there are also technical limitations to be considered in the construction of the wheel which arise chiefly from a third factor which we have not yet considered, namely, curvature.

If we are to reproduce as nearly as possible the characteristics of a level straightaway, the greatest section of the perimeter of the wheel touched at any instant by the rat must be sensibly flat. This would not be a difficult requirement if there were no limit to the available radius. Unfortunately, however, the moment of inertia of the wheel increases rapidly with the radius. For this reason our present problem is virtually to determine the greatest curvature (the smallest radius) that will still remain negligible in comparing the mechanics of running in a wheel with those of running on a flat surface. There is no very definite solution of the problem at hand. In the construction of the wheel about to be described a considerable allowance has been made: The rule has been followed that the radius of the wheel should be at least twice the greatest length of surface touched by the running rat at any time.

Since an optimal curvature remains for the present almost a matter of opinion, there is no unique set of values for curvature, moment of inertia, and friction that will most closely approximate a level straightaway. Given a curvature as low as that provided by the half-the-radius rule, the moment of inertia is determined wholly by structural considerations, for the lowest value consonant with reasonable strength and rigidity will almost necessarily be greater than the average weight of a rat. A moment of inertia equal to twice the weight of the rat might be set as a reasonable value.

Such a wheel can be greatly improved (so far as our standard of reference is concerned) by the addition of a small amount of friction. The friction damps the oscillation and thus to some extent corrects for the undesirable effect of the necessary weight of the wheel. Assuming the weight of the rat to be 175 grams and the moment of inertia 350 grams, a sliding friction of 10 grams (expressed as above) will successfully damp any ordinary oscillation within one or two cycles. Against such a friction the rat runs at a slope of a little over 3° , which is not a very significant deviation from a level path.

Certain other properties of a suitable wheel may be considered.

1. In order to insure a correct linear measure of distance run the running must take place, as we have assumed, in a single plane normal to the axis of the wheel. The pathway must consequently be wide enough to permit unobstructed running but narrow enough to prevent wandering from side to side.

2. The character of the surface must be adapted to level running but must also provide an adequate grip, both for climbing a considerable slope and for controlling the momentum of the wheel during any change in velocity.

3. The principal strain on the wheel is centrifugal. The construction must allow for the support of the weight of the rat and for the centrifugal forces present in running. A further strain, moreover, must be provided for. Direct measurements of frequency of stepping, obtained by recording the pressure exerted upon the substratum by a running rat, show that each foot may strike the surface seven or eight times per second, giving a total frequency of 28 to 32 impacts per second. This is for fairly brisk running, but a considerably higher value may well be possible. A running-wheel of the size and strength about to be described may have a natural frequency within this range. The wheel must, therefore, be constructed to stand the extra strain imposed upon it when that frequency is reached and to avoid so far as possible any extra vibration, which would be a significant source of disturbance.

4. If friction is applied to the shaft, very little torsion of the wheel about its axis should be possible. Otherwise the wheel will "whip" during any change in velocity.

5. The wheel should be quiet.

III

A wheel fulfilling these requirements may be constructed as follows:

A piece of drill rod (*C* in Figure 2), 10" x 5/16", is mounted horizontally on sets of ball bearings (*E,E*), which are pressed into holes in two (2" x 4") wooden uprights (*F,F*). The shaft carries two collars (*B,B*), each of which has six equally spaced holes in its rim, countersunk on alternate sides to receive standard bicycle spokes. The rims are 2 1/4" apart. Two aluminum tubes (cross-section shown at *A,A*), 6 feet long and with an outside diameter of 1/4", are bent into hoops with a tinsmith's bender. Six equally spaced holes are drilled radially into each hoop with a No. 38 drill. One hole comes at the juncture of the two ends and is not drilled but filed, one-half in each end, with a small round file. Bicycle spokes, 11 1/2" long, are inserted into the collars and then into the hoops, one collar being connected with one hoop only. The spokes are crossed in pairs in the usual manner. Number 3-48 nuts are screwed on the spokes outside the hoops, and tightened until the latter are firmly held. The ends of the hoops are pressed together in the process, and no other fastening is required.

At this stage the wheel consists of two aluminum hoops mounted separately upon a shaft. A strip of aluminum mesh, eight strands to

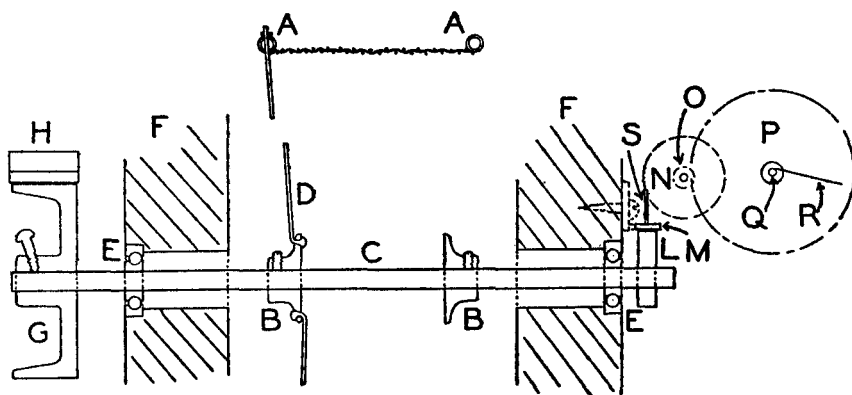


FIGURE 2

SCHEMATIC SECTION THROUGH THE AXIS OF THE WHEEL, SHOWING FRICTION-BRAKE, RECORDING DEVICE, ETC.

For details see text

the inch, 3 1/4" wide and 6 feet long (the edges being suitably hemmed) is then inserted between the two hoops. The screen rests on the inner surface of the hoops, the hem being indented at the proper places to accommodate the spokes. The screen is wired to the hoops with short pieces of aluminum wire, and the two ends of the strip are woven together.

The width of the screen is greater than the distance between the rims of the collars. The spokes consequently flare slightly outward and provide a lateral pull which is of service in truing the wheel. This is done by manipulating the tension on each spoke. A lateral variation of less than 1/4" can easily be obtained.

In order to provide a variable friction (for purposes to be mentioned later) an aluminum drum (*G*), 3" in diameter, is attached to one end of the shaft. A single layer of copper or iron wire is carefully wound about the drum to provide the friction surface. A leather brake (*H*) is arranged to be applied with any desired force by a weight and lever of variable length.

The wheel is left open on both sides. If it is mounted at least 2 feet above the nearest surface, a rat will not, under ordinary circumstances, escape. Guard plates may be mounted on the uprights if desired. A living-cage is also easily attached to either upright with a door leading into the wheel.

The significant characteristics of the wheel may be listed as follows:

Radius: 11 1/4 in. at the running-surface.

Moment of inertia: 350 grams at the running-surface.

Friction: Variable between 0.5 and 50 grams measured as heretofore.

Substratum: Aluminum mesh, eight strands per inch.

Clearance of path: 3 inches.

Rigidity: Adequate.

Torsion: Very slight for all forces likely to be met with.

Quietness: Slight rubbing sound when friction brake is used.

Otherwise practically silent.

With a friction of not less than 5 grams, such a wheel may be said to be almost as completely under the control of the rat as is the mass of the rat itself in straightaway running. There are, of course, slight mechanical differences, but when the initial adaptation to the new stimulation has taken place, the two cases can for most purposes be considered identical.

IV

The usual measurement taken with the running-wheel is the total distance run during some such period of time as a day, where the distance is expressed either in a unit of length or in revolutions of the wheel. Although such a datum has the dimensions of a velocity, it has no close relation to the actual running, since the latter is not continuous. A closer correspondence may be secured by reducing the length of the experimental period. The best representation is a continuous distance-time graph, which can be obtained experimentally with the following device:

An eccentric (L in Figure 2), attached to the shaft of the wheel, produces a reciprocal motion in the lever (M), which rests upon it. A tongue (S) fastened to the lever engages in the teeth of the ratchet (N) and turns the latter one notch forward at each revolution of the wheel, regardless of the direction in which the wheel is turned. The movement of the ratchet is reduced ten times by the gears O and P . If the ratchet has 48 teeth, the shaft (Q) turns once for each 480 revolutions of the running-wheel or for every 2880 feet run by the rat. A continuation of the shaft carries a silk thread (R) which is slowly wound up as the shaft is turned. The thread is led 2 or 3 feet from the device, at right angles to the shaft, passed over a glass ring, and fastened to a collar, which slides vertically upon a square shaft. A writing-point mounted upon the collar writes upon a kymograph drum. If the diameter of the shaft (Q) is about $1/6''$, the writing-point will move vertically 1 inch for each mile run. A further reduction in this ratio can be secured by looping the thread about a second glass ring on the collar and fastening the end to the top of the shaft.

The resulting graphs are most easily read if the tracing has a slope of 40° to 60° . The choice of kymograph speed will thus depend upon the average amount of running to be recorded per experimental period and will vary with the rats used and the conditions of the experiment.

The scale of the records given by the apparatus as described is not adapted to the finer details of the running behavior, for the relatively small coordinates will not permit reading to a single revolution of the wheel. In order to obtain a greater excursion the ratio of the gears may be changed and the shaft enlarged. The gears may even be omitted altogether and the shaft of the ratchet used to wind

the thread. An excursion of 1 inch per ten revolutions is easily obtained. A relatively fast kymograph must be used to give the records a slope at which their characteristics are clearly indicated.

In the case of large amplifications of the vertical movement of the writing-point an impractical width of kymograph paper is required. The *effective* width of the usual 6" paper may be increased ten- or twenty-fold with the device represented in Figure 3. The spool (*A*), mounted on the sliding carriage of the writing-point (*B*), carries a supply of extra thread. The spool is held from unwinding by the arm (*C*) and the catch (*D*). The entire device is supported by the thread (*F*) which goes to the running-wheel. As the carriage is drawn up, a string (*E*), fastened at one end to the lever (*D*) and at the other to the base of the stand, is drawn tight. The string is of such a length that, when the writing-point reaches the top of the drum, the lever (*D*) has been lowered to a point at which the arm (*C*) is released. The spool (*A*) immediately unwinds. The whole device drops, and the lever (*D*) catches the arm (*C*) after only one revolution of the spool. A length of thread equal to the circumference of *A* is thereby introduced into the system. If the circumference is slightly less than the width of the kymograph paper the writing-point is almost instantaneously shifted from the top to

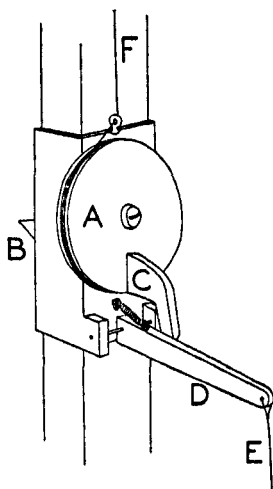


FIGURE 3

DEVICE TO INCREASE EFFECTIVE WIDTH OF KYMOGRAPH PAPER IN RECORDS OF THE TYPE HERE DESCRIBED

the bottom of the drum. The operation is repeated when the writing-point again reaches the top of the paper. The completed records must be cut vertically along the lines made by the falling point and pieced together to form a continuous graph. If the device is very light and the bearings of the lever (*D*) practically frictionless, no sensible distortion is introduced by the method.

V

It is a matter of common observation that such an organism as a rat is not continuously active. A distinction can be drawn between two general phases in its behavior, an active and a quiescent. If observed for a sufficient time the two phases recur alternately, and the behavior shows a periodicity. We are not concerned here with periodicity *per se* or with the mechanism of initiation of either phase. The reader may be referred to the papers of Richter (3) and Stier (7). We are concerned rather with the measurement of the active phase once initiated and the relation of the elicited behavior to certain independent variables. The periodicity is important, however, in its technical bearing upon the temporal conditions of an experiment.

Since the recording devices are entirely automatic, the complete apparatus may be set up under the desired conditions and the records of the behavior taken mechanically whenever the behavior is forthcoming. The rate of running can be measured in this way during a single active phase or during a series of phases. For certain purposes, however, it is convenient to make use of the fact that activity can be stored, and that when so stored the time of its elicitation can be controlled.

Suppose the behavior of a rat to be observed for successive periods of 24 hours each. The records are found to be composed of active and quiescent phases, with a possible relation between the distribution of the activity and the time at which daily care is given to the apparatus and rat. If we now introduce into the 24-hour period an interval during which access to the wheel is cut off, the remaining part of the period shows a greater activity per unit time, and the distribution is clearly related to the interval of confinement, in that the latter is followed by a relatively intense burst of activity. If the confinement is then gradually prolonged, the "density" of the activity during the rest of the period increases, until a length of interval is reached at which the remaining active period shows no

quiescent phase. The length of such a period varies with many factors but may be of the order of 4 to 6 hours.

If there is no significant diurnal change in the environment, a rat quickly adapts to running at any given hour. Consequently, an experiment can be carried out whenever the conditions of the laboratory are most suitable, especially with respect to noise. The release of the rat is easily accomplished with an ordinary alarm clock, in the following way. A short extension is attached to the alarm key, which winds up a piece of string fastened to it and draws a latch-bolt. The unlatched door is opened by a spring or counterbalance. The alarm starts the kymograph in the same way. (In order to set an alarm more than 11 hours in advance it is necessary to combine two of the usual clocks. The second clock turns on the alarm of the first after the first has passed the hour at which it would otherwise have gone off. Two clocks permit a setting slightly less than 22 hours in advance.) It has been found most convenient for the experimenter to terminate the experiment in person, although this could also be done automatically.

The following procedure has been satisfactory. The experimental period ends at 8:30 A.M. At that time the record is removed from the drum and any necessary care is given the rat. The cage is then closed, a fresh drum is placed on the kymograph, and the clock set for the release. The length of active period is determined by the time of the release. For example, the alarm is set for 3:30 A.M. if a five-hour period is desired. No other attention is required during the 24 hours.

VI

Figures 4 and 5 are reproduced from a series of records obtained with a single female rat aged 125 to 175 days. They are supported, so far as the general comment made upon them is concerned, by several hundred records from many other rats, representing several thousand experimental hours. Most of these records were obtained while the design of the wheel was being evolved through a series of trial models. More extensive observations from a single model (as described herein) are in progress. The accompanying figures are given chiefly to show the sort of result to be expected and the applicability of the method to several problems concerning activity.

The records were obtained with the wheel and procedure already described. The rat was released into the running-wheel at 3:00 A.M.

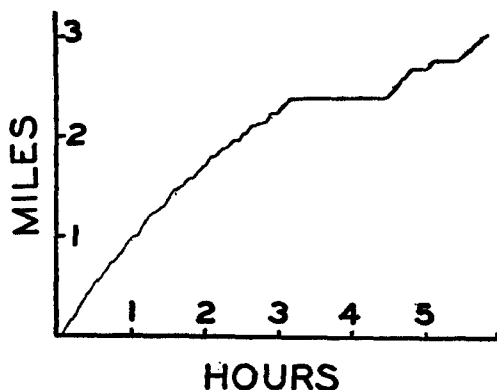


FIGURE 4

RECORD OF THE RUNNING ACTIVITY OF A FEMALE RAT DURING A ("COMPRESSED") PERIOD OF ABOUT SIX HOURS

The rate of running, given by the slope of the curve, declines in an orderly manner during the first three hours. Thereafter a greater variability is evident, but the extrapolation of the first part of the curve is nearly reached before the period ends.

and the experiments were terminated between 8:00 and 9:00 A.M. The usual precautions were observed. The temperature of the room varied less than 2°C . during the entire series of experiments and probably less than 0.5°C . during a single period. The average temperature was about 21°C . The room was dark during the running and during most of the period of confinement and was thoroughly sound-proofed. No other animals were present. Drinking water was always available.

Figure 4 is a typical daily record obtained with a friction of about 15 grams. The rate of running begins at a maximum.² During the next three hours the rate shows a gradual but remarkably smooth decline, which is best seen in Figure 4 by foreshortening the record. The variability of this part of the curve appears from inspection to be some function of the slope, increasing as the slope falls off. After three hours the record suddenly shows a greater variability (discussed below), but the extrapolation of the first part of the curve is later fairly closely approximated.

²Some rats invariably "warm up" for 15 or 30 minutes before reaching a maximal rate.

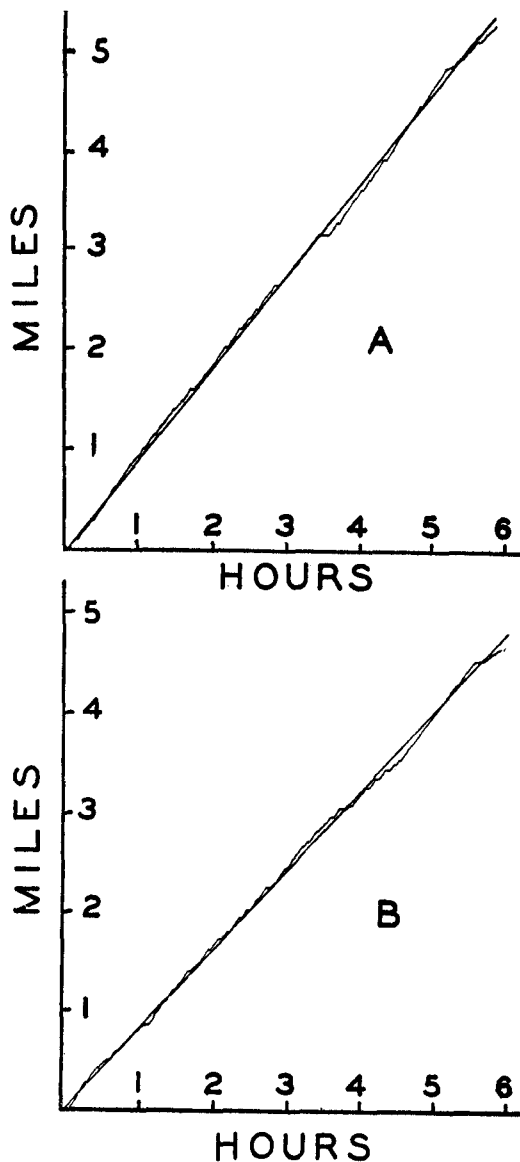


FIGURE 5

RECORDS OF THE RUNNING ACTIVITY OF THE RAT IN FIGURE 4 WHERE A CONDITIONED HUNGER CYCLE HAS BEEN BUILT UP WITH ITS PEAK AT THE SIXTH HOUR

The two records were taken on successive days. In *A* the friction of the wheel (expressed as described herein) was 14.3 grams. The slope of the straight line drawn through the curve is 52° . In *B* the friction was increased to 19.5, and the slope falls to 48° .

In order to obtain a record of this sort it is necessary to suppress the feeding behavior that would ordinarily appear during the period. This is done by attaching a cover to the food tray, which is closed at the beginning of the period by the release alarm. If this precaution is not taken, the curve is interrupted by delays for which there is no adequate compensation, and the form of the curve as revealed in Figure 4 is obscured. No very considerable hunger is developed during a six-hour period, although feeding behavior is undoubtedly suppressed.

If this procedure is repeated for several days, a conditioned hunger cycle is developed, the peak of which comes at the end of the experiment, when the rat is fed. After the rat has been fully conditioned to eat at, say, the sixth hour after the release, the form of the record changes to that shown in Figures 5*A* and 5*B*. A well-marked condition of hunger comes to be developed during the latter part of the period, which is reflected in an increase in activity. The resultant curve is essentially a straight line, if the removal of the food coincides with the beginning of the period of activity. The difference between the two types of curve is an indication of the way in which the conditioned hunger cycle is built up during the period, and, granted the possibility of a quantitative description, is thus a valuable measure of that process.

As we have seen, the rat runs in the wheel at a position such that the gravitational component acting tangentially is just equal to the friction. Given the weight of the rat (W) and the friction of the wheel (F) measured as above in grams acting vertically at the running-surface (at D in Figure 1), the position can be calculated from the simple relation

$$\frac{F}{W} = \sin \alpha$$

which is readily obtained from the construction in Figure 1. The apparatus, as described, includes a variable friction ranging from practically zero to about 50 grams. Beyond 50 grams technical difficulties are likely to arise in maintaining a constant coefficient of friction and in avoiding chattering or squeaking of the brake. The available range of slopes at which a 175-gram rat can be made to run with this wheel is, therefore, from practically zero to about 16°.

Figure 5 demonstrates also the effect of friction upon the behavior of the rat. The record *A* was obtained when the friction of the

wheel was approximately 14.3 grams. Record *B*, taken the following day, is for a friction of 19.5 grams. The straight lines drawn through the records have the slopes 52° and 48° respectively. The total record is thus modified by the change in slope, and to the same degree throughout. The exact relationship between slope and rate is under investigation.

VII

The "normal" curve representing the compressed daily activity of the rat is obtained by limiting the time during which running is possible. The compression is carried out until a length of period is reached in which no quiescent phase occurs. This is an uncertain criterion, however, since even the most active running is broken by short "quiescent" pauses. Fortunately, the nature of the resulting curve enables us to define the length of a period of complete compression without appeal to the active-quiescent distinction.

The variability of the record in Figure 4 can be estimated (for the present simply by inspection) from its deviations from a smooth curve. These are due chiefly to the appearance of short periods of no running. For the first three hours in the record in Figure 4 the variability is, as we have seen, to a certain extent related inversely to the slope of the curve, increasing as the slope falls off. At the end of the third hour there is a sudden break, and no running is observed for more than an hour. We may deal with this delay, however, not as a quiescent phase, but as a *sudden increase in variability*. The process of compression is directed toward the elimination of such a change and may be defined as complete, therefore, when the behavior during the active period shows only the orderly change in variability related to the slope of the curve.

The active period represented in Figure 4 must, then, be regarded as too long. This does not mean that the period should have ended at the third hour. The effect of compression is not felt, of course, on the day it is made. According to the technique already outlined the length of period should have been shortened progressively until successive daily records showed no sudden change in variability. A length of four and one-half or five hours might have sufficed.

An accurate determination of the length of a compressed period is important for the quantitative treatment of the behavior. It will be observed in Figure 4 (and is a general characteristic of records of this type) that after an exceptional delay there is a compensatory

increase in the rate of running, but the extrapolation of the first part of the curve is never quite reached. An equation describing the earlier part of the curve need not account adequately for the latter. Nevertheless it would be embarrassing to set an arbitrary limit to the datum to be described based wholly upon the ease of describing it. It should be noted, therefore, that the proposed definition of a compressed period is not based upon the simplicity of the resulting curve, although it has the effect of achieving it. The appeal to variability secures a limit not related to the nature of the curve. While the argument, as presented, is internal to the data, it is supported by the reasonable assumption that the sudden change in variability indicates the operation of a factor extraneous to the group previously controlling the behavior.

VIII

The word "spontaneous" was defended by Bethe (1) as properly designating a response for which the correlated stimulus was unknown. This is clearly the accepted meaning in the term "spontaneous activity." The unknown stimulus is in this case regarded as interoceptive, and many investigations of the subject have been concerned with its identification. The well-known stomach-contraction hypothesis, which, as Stier (7) has shown, was first suggested by Loeb, will serve as an example of this point of view.

For the sake of a consistent systematic use of the term stimulus, however, it should be pointed out that the stimuli that elicit running are known. The reflex mechanisms concerned with simple stepping and coordinated progression have been extensively studied. The monograph by Magnus (2) summarizes the literature up to the date of its publication. The specific stimuli are partly proprioceptive (depending largely upon the position of the limbs and the forces tending to change that position) and partly exteroceptive—visual, tactual, or of some other form. The supposed unknown stimulus implied in the use of the term spontaneous must act, not to elicit progression, but only to *facilitate* its elicitation by these proprioceptive and exteroceptive stimuli. This is an important distinction.

That an external stimulus may facilitate reflexes of progression is, of course, well known. Magnus, for example, has described the effect of a loud sound upon the progression of a thalamic rabbit (2, pp. 203-204). It is quite possible that an internal stimulus may act in a comparable fashion to provoke the phenomenon of spon-

taneous activity. However, our inferences concerning the nature of an internal factor are based upon certain observed aspects of behavior. Superficially, the outstanding characteristic of spontaneous activity is the suddenness of the transition from rest to action, and this doubtless has led to the current assumption of a *stimulus* as responsible for the change. As our description of spontaneous activity becomes further elaborated, however, the properties ascribed to an internal factor must be modified accordingly. Figure 4 suggests that the immediately antecedent central condition is not a stimulus, but a slowly changing state, the properties of which may be rather accurately inferred.

In any event the hypothesis of an internal stimulus (or state) is unnecessary in the study of spontaneous activity. Our immediate experimental material is the behavior of the rat. We start from the observation that, although a running-wheel as a source of stimulation may be constantly present, the reflexes of which running is composed are not always elicited or if elicited they vary in strength.⁸ The problem of spontaneous activity arises in this apparent variability. In solving it we need not go beyond a quantitative description of strength as a function of some such independent variable as time. The identification of a "physiological correlate," which varies in the same way, may yield supplementary information but is not essential to the solution, so far as the description of behavior is concerned.

A similar argument has been advanced in the case of hunger (5, 6). In several respects a close parallel can be drawn between these two "drives." The normal eating curve is obtained with a technique of compression similar to that described herein, and the properties of the resulting curves are obviously alike. The record in Figure 4, for example, may be compared with Figure 6, which is reproduced from an earlier paper (5) on the eating behavior of the rat. The two curves are not quantitatively identical but their great similarity is obvious. Activity, however, presents a special problem. As we have noted elsewhere (5), a condition of hunger manifests itself as spontaneous activity whenever specific stimulation leading to a characteristic response is absent. Activity *per se* must therefore be regarded as subject to external complications of this sort. The interaction of two "drives" is demonstrated in Figure 5. A comparison with Figure 4 also suggests, however, the possibility of an independent experimental manipulation of each factor. A complete analy-

⁸For this use of the term strength cf. (4) and (5).

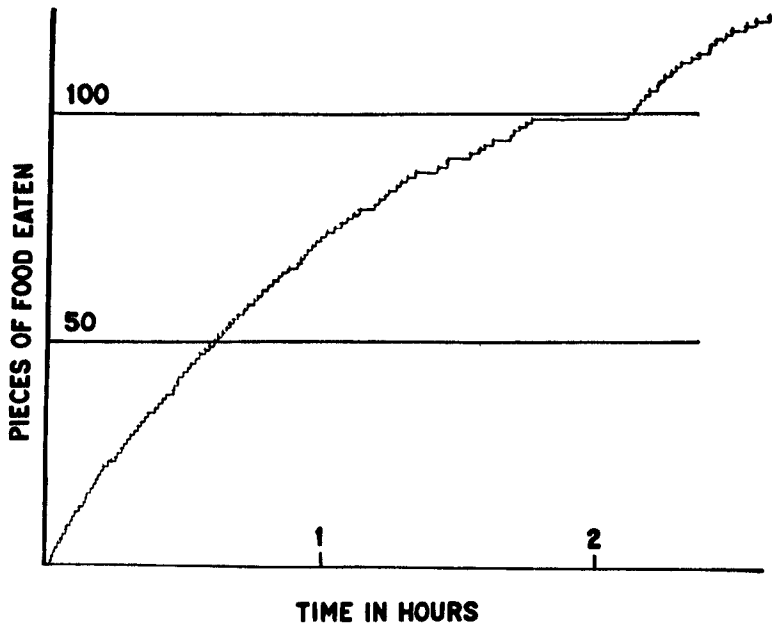


FIGURE 6

RECORD OF THE EATING BEHAVIOR OF A RAT, REPRODUCED FROM AN EARLIER PAPER (5) FOR COMPARISON WITH FIGURE 4

sis of the phenomenon should be possible with the procedure here described.

SUMMARY

The "running-wheel" measures a selected form of spontaneous activity. The behavior is dependent in part upon the properties of the wheel. The mechanics of running in a wheel are discussed. In listing the specifications of a standard wheel an effort is made to reproduce as nearly as possible the conditions of running on a level straightaway. A suitable wheel is described. The method of recording yields a continuous distance-time graph of the behavior.

The behavior of such an organism as a rat may be divided into two phases—an active and a quiescent. If any extensive activity is prohibited during part of a day, the remaining part shows a greater "density" of activity per unit time. If the period of confinement is

made sufficiently long, the resulting active period may assume certain continuous properties.

Sample records are given showing (1) the normal curve for a "compressed" period, (2) the effect of the presence of a conditioned hunger cycle, and (3) the effect of friction upon the rate of running.

The use of the term "spontaneous" implies the existence of an internal stimulus, which can act, however, not to elicit running but only to facilitate it. The inference of such an internal factor is based upon certain characteristics of the observed behavior. Its nature as a stimulus is here questioned.

The present result is compared with earlier data on rates of eating.

REFERENCES

1. BETHE, A. Das Nervensystems von Carcinus Maenas. *Arch. f. mikr. Anat.*, 1897, **50**, 460.
2. MAGNUS, R. Körperstellung. Experimentell-physiologische Untersuchungen über die einzelnen bei der Körperstellung in Tätigkeit tretenden Reflexe, über ihr Zusammenwirken und ihre Störungen. Berlin: Springer, 1924. Pp. xiii+740.
3. RICHTER, C. P. A behavioristic study of the activity of the rat. *Comp. Psychol. Monog.*, 1922, **1**, No. 2. Pp. 55.
4. SKINNER, B. F. The concept of the reflex in the description of behavior. *J. Gen. Psychol.*, 1931, **5**, 427-458.
5. ———. Drive and reflex strength: I. *J. Gen. Psychol.*, 1932, **6**, 22-37.
6. ———. Drive and reflex strength: II. *J. Gen. Psychol.*, 1932, **6**, 38-48.
7. STIER, T. J. B. "Spontaneous activity" of mice. *J. Gen. Psychol.*, 1930, **4**, 67-101.

Laboratory of General Physiology
Harvard University
Cambridge, Massachusetts

LA MESURE DE "L'ACTIVITÉ SPONTANÉE"

(Résumé)

La cage "en forme de roue" mesure une forme choisie de l'activité spontanée. Le comportement dépend en partie des propriétés de la roue. On discute la mécanique de courir dans une roue. En déterminant les spécifications d'une roue adéquate, on fait l'effort de reproduire le plus fidèlement que possible les conditions de courir sur une surface droite unie. On décrit une roue adéquate. La méthode d'enregistrer donne un graphique continu de distance et de temps du comportement.

On peut diviser le comportement d'un organisme tel qu'un rat en deux phases—une active et une tranquille. Si l'on défend une activité étendue pendant une partie d'un jour, la partie qui reste montre une plus grande

"densité" de l'activité pour le temps unitaire. Si la période d'emprisonnement est assez longue, la période active qui résulte peut montrer de certaines propriétés continues.

Comme exemples, ont donné des résultats qui montrent (1) la courbe normale d'une période "comprimée", (2) l'effet de la présence d'un cycle de faim conditionnel, et (3) l'effet de la friction sur la vitesse de courir.

L'emploi du terme "spontanée" implique l'existence d'un stimulus intérieur, qui ne peut agir, d'ailleurs, pour causer l'action de courir mais seulement pour la faciliter. La supposition d'un tel facteur intérieur est basée sur certains traits du comportement observé. Ici on met en doute sa nature comme stimulus.

Ce résultat est comparé aux données antérieures sur les vitesses de manger.

SKINNER

DIE MESSUNG DER "SPONTANEN TÄTIGKEIT"

(Referat)

Durch das "Laufrad" ["running-wheel"] wird eine besondere Form der spontanen Tätigkeit gemessen. Die Tätigkeit ist teilweise von den Eigenschaften des Rades abhängig. Es werden die Mechanismen des Radlaufens besprochen. Bei der Notierung der Anforderungen [specifications] eines Normalrads [standard wheel] hat man versucht, so genau wie möglich die Umstände des Laufens auf einem flachen Pfad nachzubilden. Es wird ein geeignetes Rad beschrieben. Die Methode der Notierung liefert eine fortlaufende graphische Registrierung des Zeit-Distanzverlaufs [time-distance graph] der Tätigkeit.

Die Tätigkeit eines Organismus wie die Ratte lässt sich in zwei Phasen teilen,—eine aktive und eine ruhende. Wenn, während eines Teiles des Tages, ausgedehnte Tätigkeit verhindert wird, weist der übrige Teil des Tages eine dichtere Konzentrierung [greater "density"] der Tätigkeit per Zeiteinheit auf. Wird die Zeit der Einschränkung genügend lang ausgedehnt, so kann die folgende aktive Periode gewisse Eigenschaften der Beständigkeit annehmen [assume certain continuous properties].

Als Beispiele werden einige Registrierungen vorgelegt, durch welche (1) die Normalkurve einer Periode der "Einschränkung" ["compressed" period], (2) die Einwirkung eines bestehenden bedingten Hungerkreises [conditioned hunger cycle], und (3) die Einwirkung der Reibung auf die Schnelligkeit des Laufens aufgewiesen, werden.

Der Gebrauch des Ausdrucks "spontan" besagt das Bestehen eines inneren Reizes, der aber nicht das Laufen bewirken, sondern es nur erleichtern, kann. Die Folgerung einer solchen inneren Einwirkung stützt sich auf gewisse Eigenschaften der beobachteten Tätigkeit. Ihre Beschaffenheit als Reiz wird hier in Frage gestellt.

Der gegenwärtige Befund wird mit früheren Befunden in Bezug auf die Schnelligkeit des Essens verglichen.

SKINNER